

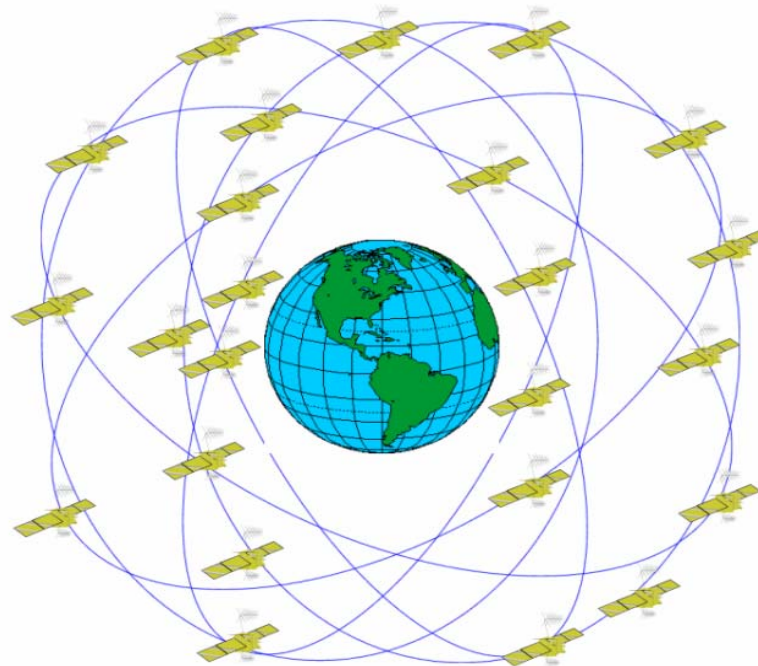


# ***DEVELOPMENT OF GLOBAL POSITIONING SYSTEM PREDICTION TOOLS TO SUPPORT FLIGHT PLANNING***

**Volpe**  
National  
Transportation  
Systems  
Center

U.S. Department  
of Transportation

Research and  
Special Programs  
Administration



**Jon Parmet, Jayne Rossetti, Karen Van Dyke DOT/Volpe Center**

**April 29, 2004**



# *Outline*

**Volpe**  
National  
Transportation  
Systems  
Center

U.S. Department  
of Transportation

Research and  
Special Programs  
Administration

- Overview
- Existing GPS Prediction Systems
- WAAS Outage Prediction System
- Challenges
- Future Direction



# *GPS Outages – How Do You Report?*

**Volpe**  
National  
Transportation  
Systems  
Center

U.S. Department  
of Transportation

Research and  
Special Programs  
Administration

- GPS is Different From Ground-Based Navaids
  - Impact of Satellites Out of Service Not Intuitively Known
  - Areas of Degraded Coverage Not Stationary
- Pilots/ATC Need to Know Where and When GPS is Not Available
- A Predictive Coverage Model is Required
  - Needs to Incorporate Status, GPS SVs, WAAS/LAAS Assets, and Airfield Database



# *GPS Outage Prediction System - Deployments*



U.S. Department  
of Transportation

Research and  
Special Programs  
Administration

- Joint FAA/Air Force RAIM Prediction System Deployed in 1995
- Australian RAIM Prediction System Deployed for AirServices Australia (ASA) in 1998
- German RAIM Prediction System Deployed for Deutsche Flugsicherung (DFS) in 1998
- AUGUR Prediction Tool Deployed by EUROCONTROL in 1998
- WAAS (LNAV only) Graphical Prediction System Deployed as Prototype for Capstone Project in 2003
- WAAS (LNAV, LNAV/VNAV, LPV) Prediction System Deployed for FAA in 2003



# *U.S. GPS RAIM Prediction System*

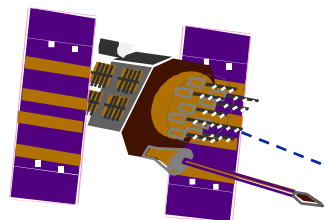


U.S. Department  
of Transportation

Research and  
Special Programs  
Administration

- GPS System Declared IOC in late 1993
- Joint FAA /Air Force RAIM Prediction System Deployed in 1995
  - Receives GPS Satellite Outages from GPS Master Control Station
  - Issues Domestic and International GPS SV NOTAMs
  - NPA RAIM Outages Available to Military Pilots as M-Series NOTAMs
  - NPA RAIM Outages Available to Civilian Pilots as Aeronautical Information from Flight Service Stations

**DOD**



**\*ALMANAC  
DATA**

**FAA**

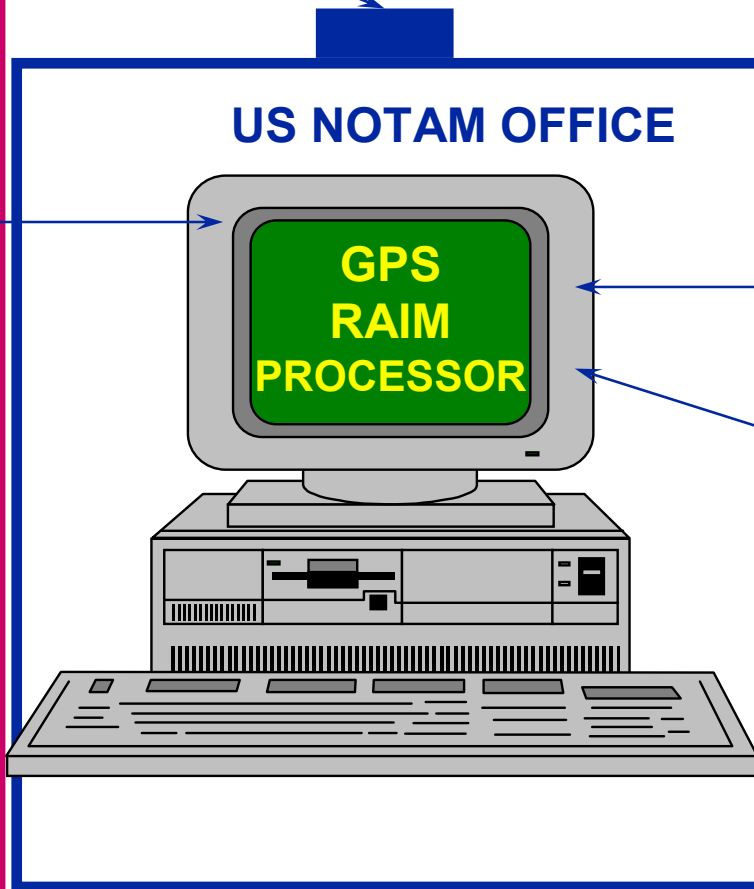
**FAA/DOD**



**FAX**

**\*UNSCHEDULED  
SV EVENTS**

**\*SCHEDULED SV  
MAINTENANCE**



**US NOTAM OFFICE**

**GPS  
RAIM  
PROCESSOR**

**CLASS  
ONE  
NOTAM**

**US NOTAM  
SYSTEM**

**INT'L  
AFTN**

**Military  
Civilian**

**AWP  
(2)**

**AERONAUTICAL  
INFORMATION**

**FSDPS  
(21)**

**AFSS  
(61)**

**CIVIL  
USERS**



# *Australian GPS RAIM Outage Prediction System*

**V**olpe  
National  
Transportation  
Systems  
Center

U.S. Department  
of Transportation

Research and  
Special Programs  
Administration

- Australian RAIM Prediction System Deployed for AirServices Australia (ASA) in 1998
- NPA RAIM Outages reported for Southern Pacific region (Australia, New Zealand, Fiji) and select locations within Canada.
- Available to pilots via National Aeronautical Information Processing System (NAIPS) briefing tool or by using Faxback (AvFAX) capability.
- Also available on the Web at:

**<<http://www.airservicesaustralia.gov.au>>**



# Airservices Australia Web Site

**V**olp  
Nation  
Trans  
System  
Centre

U.S. Department  
of Transportation

Research and  
Special Program  
Administration

Airservices Australia - Netscape

http://www.airservicesaustralia.com/default.asp

Airservices Australia

www.airservicesaustralia.com

**AIRSERVICES AUSTRALIA**

Home

**SAFETY NO. 1**

Airservices Australia is a business providing air traffic management, air navigation infrastructure services and aviation rescue and firefighting.

- Corporate Profile
- Pilot Centre
- Newsroom & Information
- Products & Services

**CUSTOMER NEWS FLASH**

**Customer News Flashes**

Latest Information for our customers.

**EXPRESSIONS OF INTEREST**

Employment opportunity for Air Traffic Controllers to work in Hawaii, Guam and Saipan

(More Information)

**ADSB PROGRAM**

Airservices Australia plans nationwide deployment of ADS-B.

(More Information)

**AIRPORT FIRE SERVICES**

Aviation Rescue and Fire Fighting services tailored to your national or international requirements.

(More Information)

**ATM Performance Reports**

Daily weekday peak hour arrival performance reports for Brisbane, Sydney and Melbourne airports.

(More Information)

**PILOT BRIEFING**

Pilot Briefing

**Publications Unit**

Publications Unit

**AvCAT**

Library Catalogue

**Site Navigation**

- Sitemap / Search
- Online Services
- Contact Us
- What's New

[Tenders](#)

[Employment Opportunities](#)

[Aviation Links](#)

Sitemap / Search / Online Services / Contact Us / What's New / Privacy & Copyright / Aviation Links / Employment





# Australian GPS RAIM Briefing Selection

**Volpe**  
National  
Transportation  
Systems  
Center

U.S. Department  
of Transportation

Research and  
Special Programs  
Administration

NAIPS Pilot Access - Netscape

File Edit View Go Communicator Help

Back Forward Reload Home Search Netscape Print Security Stop

Bookmarks Location: <http://www.airservices.gov.au/brief/briefr.htm> What's Related

Instant Message Internet Lookup New&Cool

Briefing

Home Search Feedback Sitemap Help

## NAIPS Pilot Briefing

**Briefing** Flight Notification GPS RAIM Charts

Click on the tabs above for more options.



AIRSERVICES AUSTRALIA

**Pilot Information**

User ID Password

Login

- Logoff from NAIPS
- Pilot Briefing Contacts
- NAIPS Registration
- UTC Time Check
- AvFax Account Enquiry
- AvFax Product Enquiry
- AIS/MET System
- GPS RAIM - International

Download User Documentation

© Airservices Australia. All rights reserved. [Disclaimer](#)

Document: Done



# *German GPS RAIM Outage Prediction System*



U.S. Department  
of Transportation

Research and  
Special Programs  
Administration

- German RAIM Prediction System Deployed for Deutsche Flugsicherung (DFS) in 1998
- NPA RAIM Outages reported for European region (Germany and select partners).
- German locations available as NOTAMs.
- Also available on the Web at:

**<<http://www/dfs.de>>**

- “International” locations sent to respective host country via Aeronautical Fixed Telecommunications Network (AFTN). Information not sent as NOTAM but as “outage information” due to regulations regarding NOTAMs.



# *DFS Deutsche Flugsicherung Web Site*

**Volpe**  
National  
Transportation  
Systems  
Center


U.S. Department  
of Transportation

Research and  
Special Programs  
Administration

Back Forward Reload Home Search Netscape Print Security Stop

Bookmarks Location: <http://www.dfs.de/> What's Related

Instant Message Internet Lookup New&Cool RealPlayer

 DFS Deutsche Flugsicherung

Flight Preparation <i>transmission online</i>	Media Services Customer Relations	Job Consulting	Air Traffic Statistics
--	--------------------------------------	-------------------	------------------------

**NEUES  
AUF DER  
HOMEPAGE**

Document: Done



**Volpe**  
National  
Transportation  
Systems  
Center

U.S. Department  
of Transportation

Research and  
Special Programs  
Administration

# GPS RAIM Briefing

Back Forward Reload Home Search Netscape Print Security Stop

Bookmarks Location: <http://www.dfs.de/raim/> What's Related

Instant Message Internet Lookup New&Cool RealPlayer

**SERVICE** **Luftraum und Verfahren**

**Pilotenservice**

**Advanced AIS**

**Flugberatung**

**Büro-NfL**

**Richtlinien**

**FIS-Fluggrundfunk**

**Luftraum und Verfahren**

**BACKGROUND**

**NEWS**

**JOB**

Number of GPS Satellites in Constellation: 27

PRN# 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25, 26, 27, 29, 30, 31

Satellite(s) Scheduled Out of Service:

PRN	Start	End
17	000509 16:00	000510 04:00
22	000511 18:15	000512 06:15

Number of Operational SVs: 26

NPA RAIM OUTAGES (Based on 5.0 Degrees Mask Angle):  
Outages >= 5 Minutes in Duration Reported

ID	Start	End	Duration (min)
EDAC	000509 12:56	000509 13:01	5
EDAC	000510 12:52	000510 12:57	5
EDAH	000509 12:48	000509 13:03	15
EDAH	000510 12:44	000510 12:58	14

Document: Done



# *Alaska Capstone Outage Reporting System*



U.S. Department  
of Transportation

Research and  
Special Programs  
Administration

- WAAS Graphical Prediction System Deployed as a Prototype for FAA Capstone Project in March 2003

- Integration of Software onto NAS Aeronautical Information Management Enterprise System (NAIMES) Platform at FAA Command Center
- Outage information available via web-based interactive GIS at:

**<<https://www.waasaps.naimes.faa.gov/Capstone/>>**



# Capstone Outage Reporting System Web Site

**V**olpe  
National  
Transportation  
System  
Center

U.S. Department  
of Transportation

Research and  
Special Program  
Administration





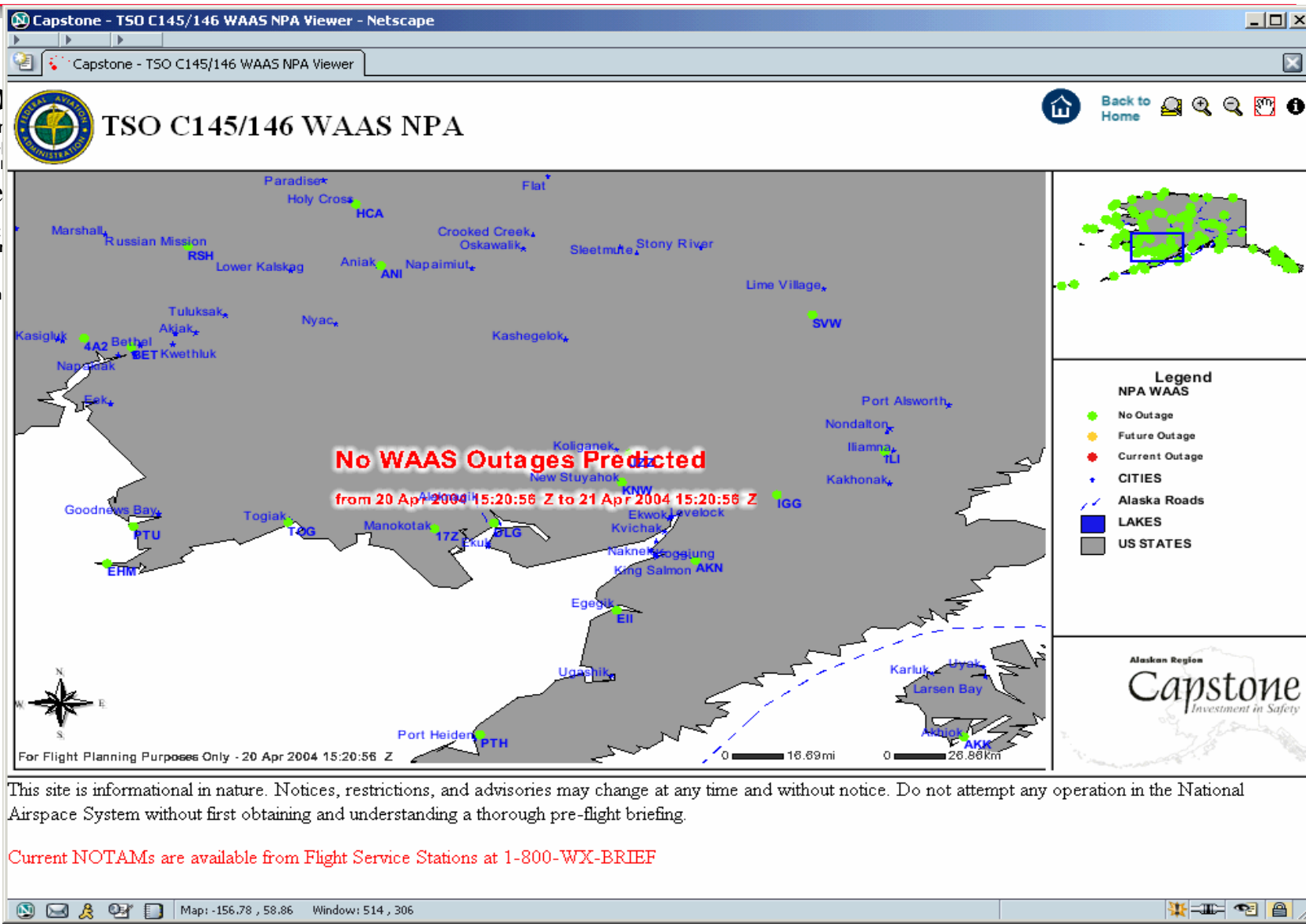


# Capstone Web Site – NPA Availability Display

**Volpe**  
National  
Transportation  
Systems  
Center

U.S. Department  
of Transportation

Research and  
Special Program  
Administration



This site is informational in nature. Notices, restrictions, and advisories may change at any time and without notice. Do not attempt any operation in the National Airspace System without first obtaining and understanding a thorough pre-flight briefing.

Current NOTAMs are available from Flight Service Stations at 1-800-WX-BRIEF



# *FAA WAAS Outage Prediction System*

**V**olpe  
National  
Transportation  
Systems  
Center

U.S. Department  
of Transportation

Research and  
Special Programs  
Administration

- WAAS Prediction System Deployed for FAA at WAAS IOC in July 2003
  - Integration of Software onto Solaris Platform located at FAA Command Center
  - Incorporates WAAS Asset Data (Geostationary SVs, Reference Stations, etc.)
  - Area-Wide Outages sent as NOTAMs Directly to United States NOTAM System (USNS).
  - Airfield-Specific Outages sent to Flight Service Stations in NOTAM Format. FSSs Issues NOTAMs to USNS.





# *WAAS Outage Prediction*

**Volpe**  
National  
Transportation  
Systems  
Center

U.S. Department  
of Transportation

Research and  
Special Programs  
Administration

- Computes WAAS HPL and VPL for each location (grid point or airfield) once per day for the following 30 hours
  - Algorithm Based on TSO C145/146 Receiver Criteria
  - Data Calculated At One-Minute Intervals
  - Automatically Re-Computed Based on an Unexpected Change in WAAS/GPS Status.
- Reverts to Computing RAIM (LNAV only) if WAAS is Unavailable
- Determines if Protection Level(s) Exceed Alert Limit(s)
- Determine if the Outage Duration is Greater than the Minimum Reportable Outage Time, i.e. Whether a NOTAM Should be Issued



# *WAAS Outage Prediction*

**Volpe**  
National  
Transportation  
Systems  
Center

U.S. Department  
of Transportation

Research and  
Special Programs  
Administration

- **En Route Predictions**

- Computed for Set of Grid Points at 1 Min. Time Intervals
- Determine if  $HPL > HAL$

$HAL = 2.0 \text{ nmi}$

- **Approach Predictions**

- Computed for Set of Airports at 1 Min. Time Intervals
- Determine if  $HPL > HAL$  and  $VPL > VAL$

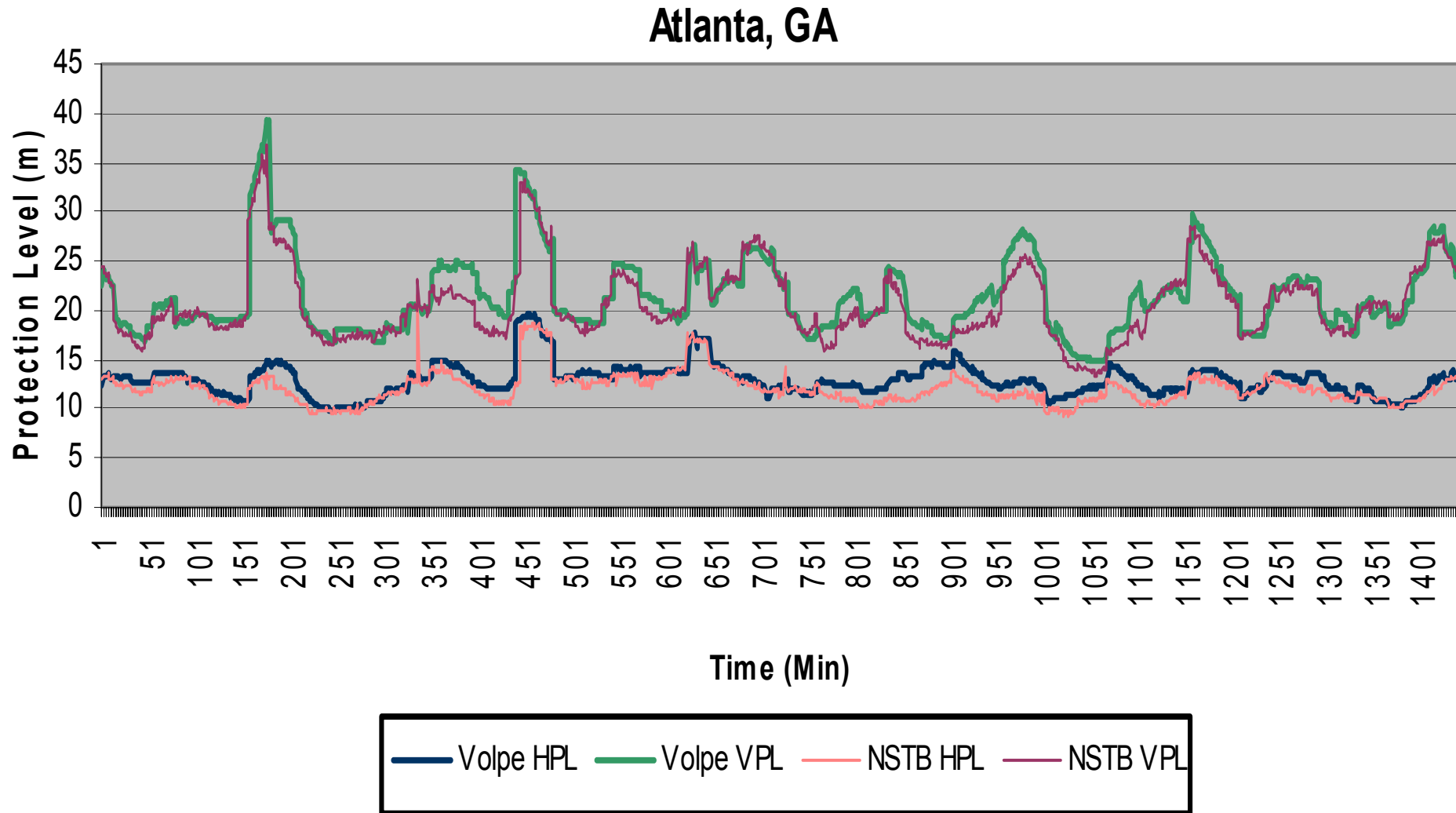
$LNAV \quad HAL = 0.3 \text{ nmi}$

$LNAV/VNAV \quad HAL = 0.3 \text{ nmi} \quad VAL = 50\text{m}$

$LPV \quad HAL = 40\text{m} \quad VAL = 50\text{m}$



# *WAAS Representative HPL/VPL Data*



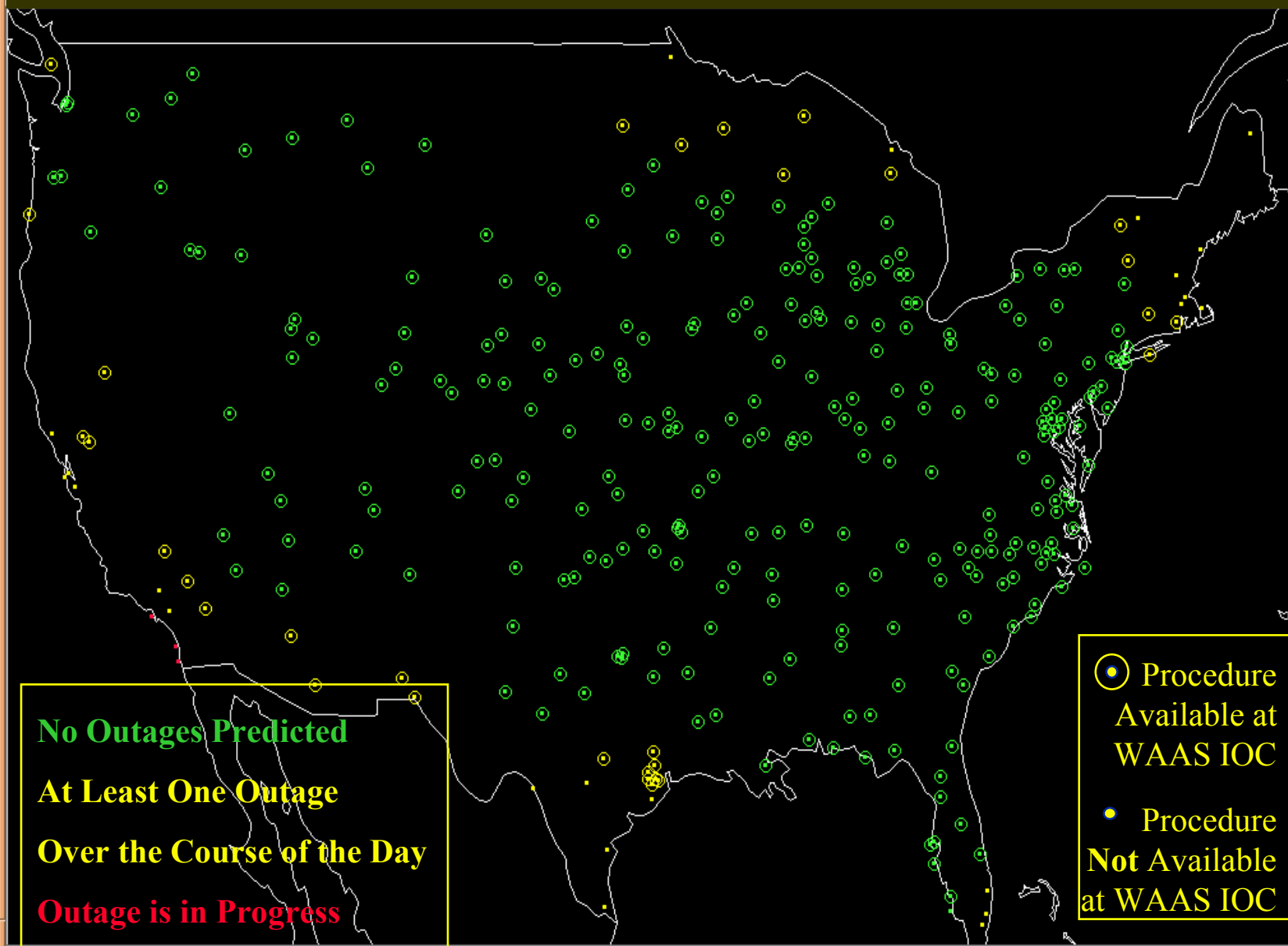


**V**olpe  
National  
Transportation  
Systems  
Center

U.S. Department  
of Transportation

Research and  
Special Program  
Administration

## Airfield-Specific WAAS LNAV/VNAV Unavailability



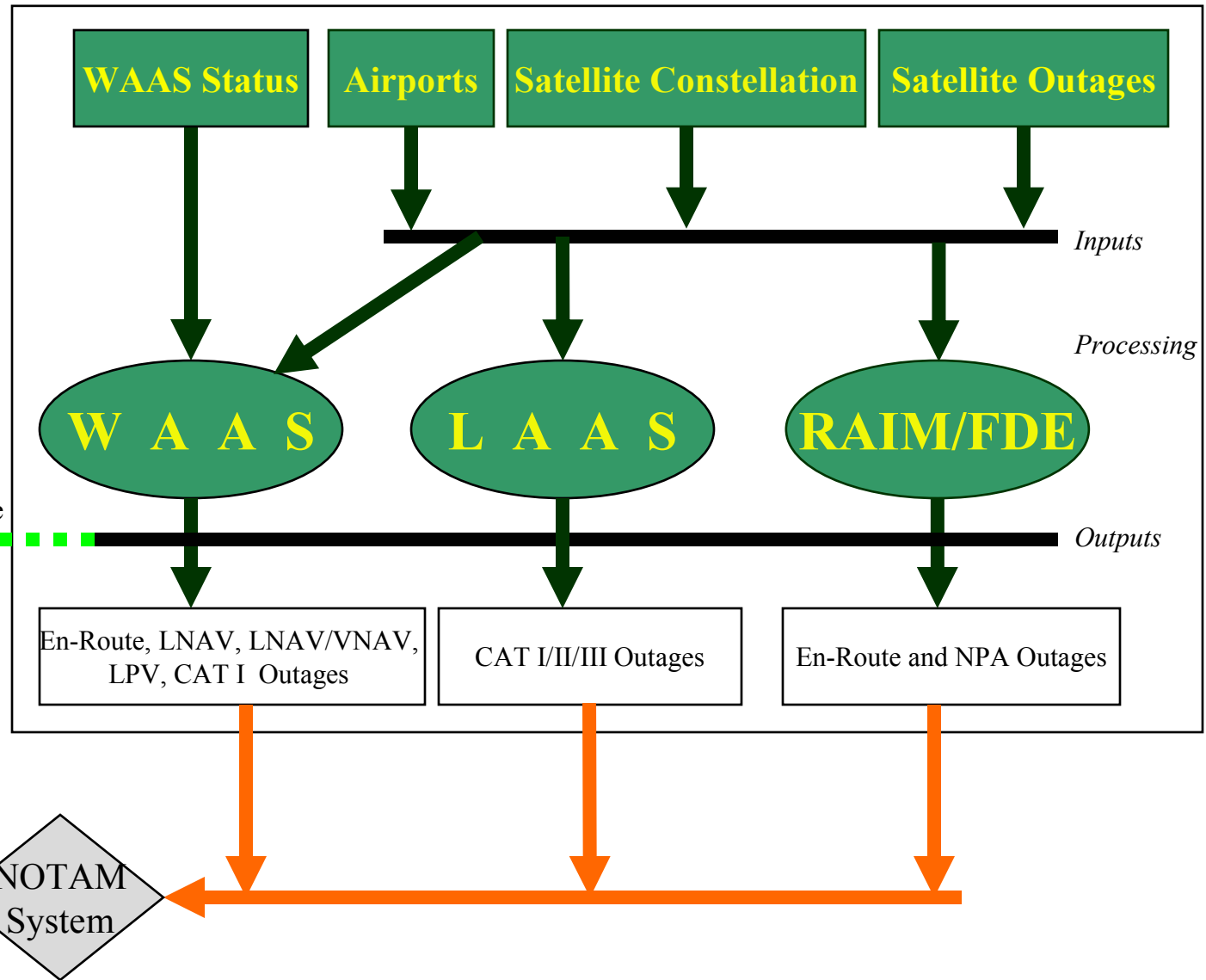
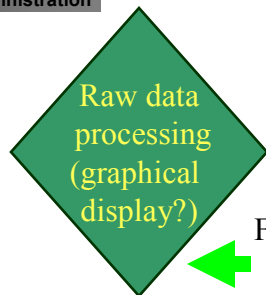


# GPS Outage Prediction System - Dataflow

**Volpe**  
National  
Transportation  
Systems  
Center

U.S. Department  
of Transportation

Research and  
Special Programs  
Administration



Prediction System  
requires NOTAM  
NUMBER in  
case NOTAMC  
needs to be issued.



# *Challenges to the Prediction Capability*

**Volpe**  
National  
Transportation  
Systems  
Center

U.S. Department  
of Transportation

Research and  
Special Programs  
Administration

- **Predicting Impact of Ionospheric Activity on GPS and Augmentation Systems is Non-Trivial**
  - How Long Does an 'Event' Last? Reacting to Iono Event May Produce NOTAMs Whose:
    - Duration Overbounds Actual Outage
    - Information That Changes Quicker Than User Can Process It
- **Short Duration Outages**
  - Should They Be Reported as NOTAM? How short?
  - Is There a Better Method for Reporting?
- **Hybrid Systems (e.g. GPS/INS, WAAS/EGNOS, GPS/Galileo, GPS/Galileo/GLONASS)**
  - Some Combinations Nearly Impossible to Predict
  - Will Pilot Know What Mix of Sensors Are OnBoard?



# *Challenges to the Outage Reporting Capability*

**Volpe**  
National  
Transportation  
Systems  
Center

U.S. Department  
of Transportation

Research and  
Special Programs  
Administration

- Dissemination Of Outage Information That is More *Accessible* To Pilots (i.e. NOTAMS, DUATS, WEB-BASED)
- Dissemination Of Outage Information That is *Meaningful* To Pilots
  - Need to Distinguish Between Outage Information from Different Types of GPS Augmentation Systems and Hybrid Systems to Provide Meaningful Information to Pilots



## *Future Direction*

**Volpe**  
National  
Transportation  
Systems  
Center

U.S. Department  
of Transportation

Research and  
Special Programs  
Administration

- **Incorporate Future Modifications to WAAS into Prediction Model**
  - Additional Ground Reference Stations
  - Additional GEOs
  - WAAS FOC 2007 (Refinements to Algorithm)
- **Develop and Validate LAAS Predictions**
- **Incorporate Graphical Interface Capability**
  - Data Fusion (e.g. Overlaying Regions of Weather, GPS Interference, etc.)
- **More Information Embedded or Sent Directly to Cockpit (Real or Near Real Time)**